Progress and challenges in NDE of composites using obliquely insonified ultrasonic waves

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ABSTRACT

The high stiffness to weight ratio, low electromagnetic reflectance and the ability to embed sensors and actuators have made fiber-reinforced composites an attractive construction material for primary structures. The multiple step production process and the non-homogeneity with brittle matrix make composites susceptible to the formation of many possible defects throughout their life cycle. Another limiting factor in widespread use of composites is their high cost - composite parts are about an order of magnitude more expensive than metallic parts. The cost of inspection is about 30% of the total cost of acquiring and operating composite structures. This large portion of the total cost makes the need for effective inspection critical not only to the operational but also to the cost benefit of these materials. The conventional inspection methods are capable of providing limited and mostly qualitative information about defects and material properties.

Obliquely insonified ultrasonic waves have shown great capabilities in providing information about flaws characteristics and material properties of composite materials. Two of leading methods have been the polar backscattering and the leaky Lamb wave (LLW) techniques, where either a single transducer is used as a transmitter/receiver or two transducers are used in a pitch-catch arrangement. These phenomena have been discovered in 1979 and 1982, respectively, and have shown great capabilities and promise with regards to NDE of composite materials as well as bonded joints and other applications. These capabilities made these two methods attractive quantitative NDE tool and the phenomena were studied extensively, particularly the LLW. The wave behavior in multi-orientation laminates has been well documented and for plate waves the analysis was corroborated experimentally with high accuracy. Recently, the authors significantly enhanced the experimental capability by increasing the speed of the data acquisition, the number of LLW modes that can be identified and the accuracy of the data inversion. In spite of the theoretical and experimental progress, methods that employ oblique insonification of composites are still not being applied as standard industrial NDE methods. The authors investigated the issues that are hampering the transition of the obliquely insonified ultrasonics to industrial applications and identified several key issues. The progress and challenges in NDE of composites using oblique insonification will be reviewed and discussed in this paper.